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Institute for Applied Materials

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# Inkjet printing of dielectric ceramic/polymer composite thick-films for flexible applications

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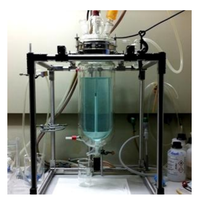
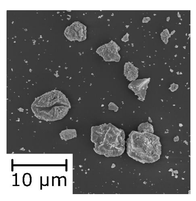
## Abstract

Recently there has been a large interest in using inkjet printing for the manufacturing of electronic components.The fabrication of printed capacitors on polymer substrates requires materials with high permittivity combined with a good processability. Ferroelectric ceramics like barium strontium titanate (BST) exhibit excellent permittivity, but their use is limited due to their high sintering temperature. In contrast, organic polymers are known for high mechanical flexibility and good processability but low permittivity. A combination of both types of material in polymer/ceramic composites allows a property tailoring. This poster shows a novel preparation route for BST/Poly(methyl methacrylate) (PMMA) composite dispersions for inkjet printing. BST/PMMA inks with different ceramic-polymer ratio were prepared and characterised with respect to their printability.

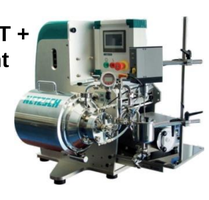
## BST Dispersion



Spray Drying
Calcination




10 v/v % BST +
Dispersant



*Material:* $Ba_{0,6}Sr_{0,4}TiO_3$

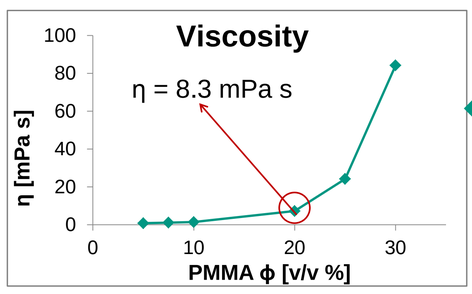
*Solvent:* Butyldiglycol (BDG)

*Dispersant*: Dolacol D1001

BST dispersion development and properties [1]

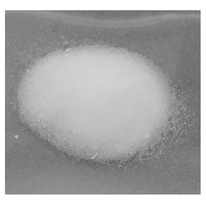
| | $d_{50}$ [nm] | $\eta$ [mPa·s] | ρ [g/cm³] | $\gamma$ [mN/m] | P [hPa] |
|---|---|---|---|---|---|
| **BST dispersion** | 200 | 13.2 | 1.2 | 30 | 0.02 |

## PMMA Solution

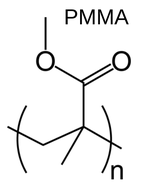



Butanone

+



PMMA



$M_W$ = 15000 g/mol

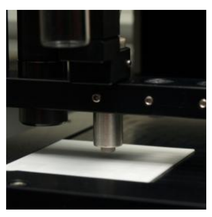
| | $\eta$ [mPas] | ρ [g/cm³] | $\gamma$ [mN/m] | P [hPa] |
|---|---|---|---|---|
| **PMMA solution** | 8.3 | 0.88 | 24 | ~105 |

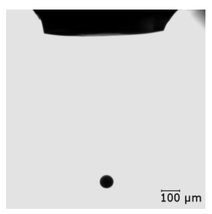
## BST/PMMA Composite Inks

**Ink characteristics**

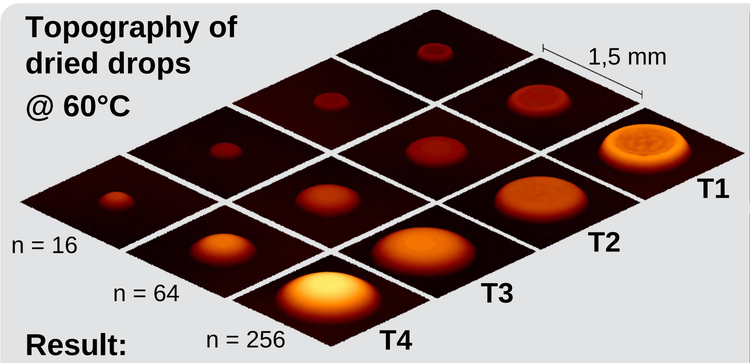
| Ink | Solids ϕ [v/v %] | BST : PMMA | Viscosity η [mPas] | BDG ϕ [v/v %] | Butanone ϕ [v/v %] |
|---|---|---|---|---|---|
| **T1** | 11 | 75 : 25 | 13.4 | 72.0 | 16.0 |
| **T2** | 12 | 67 : 33 | 11.2 | 77.1 | 11.4 |
| **T3** | 13 | 50 : 50 | 10.2 | 60.0 | 26.7 |
| **T4** | 16 | 33 : 67 | 9.7 | 36.0 | 48.0 |

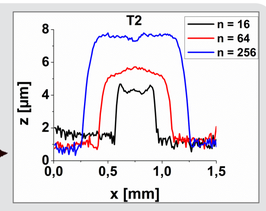
→ Inks suitable for various printheads

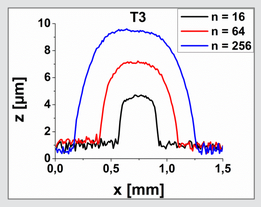





**Topography of dried drops @ 60°C**



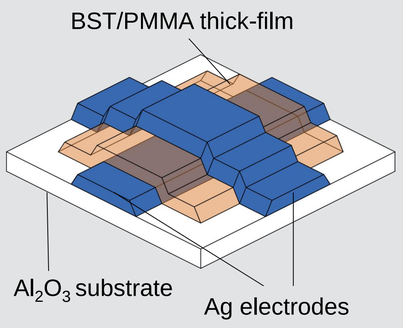



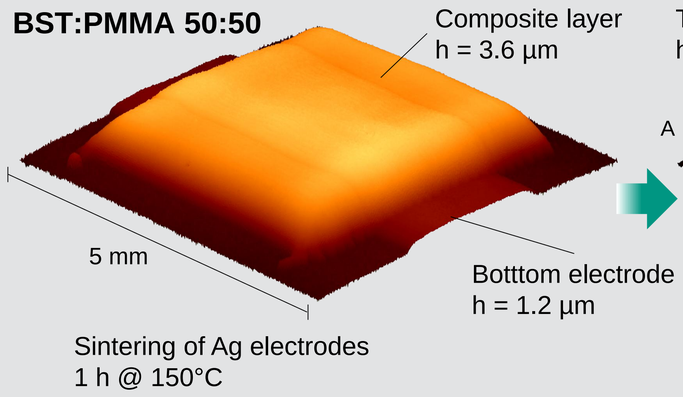

**Result:**
Inks suitable for preparation of homogenous films

## Inkjet Printing of Metal-Insulator-Metal Capacitors

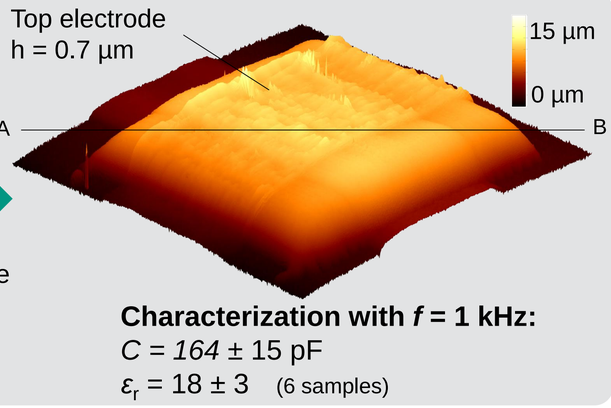
**Capacitor layout**




**BST:PMMA 50:50**

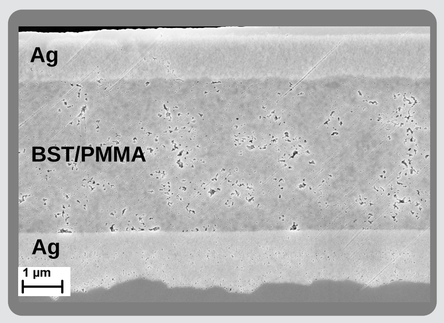



Sintering of Ag electrodes
1 h @ 150°C




**Characterization with *f* = 1 kHz:**
*C* = *164* ± 15 pF
$\varepsilon_r$ = 18 ± 3 (6 samples)

**Cross sectional image**




## Conclusion

This Poster shows a novel preparation route for BST/Poly(methyl methacrylate) (PMMA) composites via inkjet printing. A BST dispersion was mixed with a 20 v/v % PMMA solution to obtain composite inks with different ratio of BST/PMMA. The composite inks were characterized in respect to their rheology and drying behavior. Fully inkjet printed metal-insulator-metal capacitors were fabricated and their dielectric properties characterized. The maximum process temperature of 150°C allows printing on flexible polymer substrates. These results show that the usage of composite inks for inkjet printing is a promising option to fabricate composite thick film components for flexible applications.

## Acknowledgement

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DFG

**Literature:**
[1] A. Friederich et al., “Rheological control of the coffee stain effect for inkjet printing of ceramics”, *J. Am. Ceram. Soc.* 96.7 (2013)